digits on the left side, while the two sets are continuous on the right paw, as in Prof. Meldola's kitten.

All the observations recorded in this paper were made in Oxford. The abnormality has now been observed through nine generations, and I have recorded notes of ten families, so that now there is sufficient material to present in a tabular form.

The notes given in this paper are much more complete than before, because the families were born in my own house or in that of a friend living near, who kindly gave me every opportunity of making notes. The results, however, would have been far more extensive if I had received intelligence of the birth of families in various quarters to which kittens had been sent.

I believe there is little doubt that the next period of three years will produce much better results in this way, for at the recent meeting of the British Association at Birmingham I exhibited the cats, and was able to give away three abnormal females to scientific gentlemen (Prof. Haddon, Prof. Meldola, and Mr. W. White) who I am sure will assist me by sending complete accounts of all the families born. I remarked in my last paper on the immense strength of heredity which was shown in the observations then recorded, remembering that the results were in all cases due to the mothers of the families. The continued observations now published serve to illustrate the same facts. As I said before, "it is practically certain that the fathers of the families have always been normal." There has, indeed, been an abnormal male cat in Oxford for the last two years—one of my kittens which I gave to Prof. Moseley for a museum specimen, and which has been kept in order that it may be quite mature. But this cat lives at some distance from my house and that of the friend to whom I gave the female kitten in 1885, and it has never been seen in our neighbourhood, while numbers of normal cats have been seen in company with our abnormal females. But nevertheless a family containing abnormal kittens was born in a house near that in which Prof. Moseley's cat is being kept, and of which, of course, the latter must be the male parent. Unfortunately, as in so many other cases, I was unable to obtain any data, and the kittens are, I believe, all dead.

We therefore see in these observations a proof of the extraordinary ease with which a distinct breed can be produced from a spontaneously appearing variety. In spite of all the swamping effect of continual and uninterrupted crossing with the normal form, I have never been able to record a normal family, while in many cases some of the kittens were equal to, or even beyond, the abnormal parent in her peculiarity. This being the case, it is clear that a breed would have been quickly established if abnormal males had been selected to pair with the abnormal females. These observations have, therefore, an interesting bearing upon the existence of such a local breed as the tailless Manx cats, as Prof. E. Ray Lankester pointed out to me when talking over the subject. Prof. Lankester supposes that a tailless individual appeared spontaneously, and that it was considered interesting and a curiosity; and when the abnormality re-appeared in some of the offspring, these were kept in preference to the normal forms. It seems quite certain that the result might have been produced in this way, and I have arranged with Dr. Grabham, of Madeira, that some of my abnormal kittens shall be sent to him to turn loose upon some neighbouring Atlantic rock on which rabbits are the only other living mammals. I should add that Prof. Lankester found a support for the theory of the origin of the Manx breed of cats in the fact that there are tailless breeds of other animals which are also fashionable in the locality, and which seem to point to the existence of the same peculiarities of taste working upon a spontaneous variety. In fact, as Prof. Lankester suggested, the people may have rather looked out for other tailless or abnormally short-tailed animals, when their interest had been excited by the existence of one such breed. But the observations here recorded have also a bearing upon those cases in which natural, instead of artificial, selection has been the agent. Granting, as I believe we must do, that some adaptive characters of great importance owe their beginning to flashes of structural or functional originality—appearing suddenly and spontaneously in one individual, as the extra digits appeared in the ancestor of my cats,—we see from these observations that in spite of all the effects of constant intercrossing with normal forms, there would be a most persistent offer of material upon which natural selection might work, for the variation would appear to a greater or less extent in a very large proportion of the individuals of the various families produced, while again and again the peculiarity would be inherited in a form equal to or even beyond that of the parent. It is therefore of interest to actually test a few instances in as complete a manner as possible, taking care that only one parent possesses the abnormality, for this is what must have happened for the first few generations of any such variety which originally appeared *in a single individual in a natural state. It is chiefly* with the object of adding another to the instances already known and worked out that these observations have been undertaken, and will be continued and rendered as complete as possible. It need scarcely be pointed out that such instances differ essentially from all the cases in which breeds of domestic animals have been established, for in these well-known and numerous breeds heredity has had undisturbed possession of the field, without any confliction between the normal and abnormal forms, except indeed in the case of the first family produced by the original parent of certain breeds of which the peculiarity appeared spontaneously in a single individual, as in the breed of "otter" sheep.

EDWARD B. POULTON

LIGHTHOUSE ILLUMINANTS[1]

THE details of the construction of the three towers and lanterns, and of the lenses and lamps in each lantern, of the magneto-electric machines, and of the gas-works, have no doubt been placed on record, and will be reported by the Trinity House engineers. But the following may serve as a general description of the arrangements.

Three low towers, constructed of massive timber, have been erected in a line inland from the higher of the two permanent lighthouses on the South Foreland, the nearest being 245 feet distant from the lighthouse, and the three being separated one from another by intervals of 180 feet. Their height, varying with the level of the ground, so that the lanterns may be on the same level, is from 20 to 30 feet; upon these structures rest three similar lanterns about 20 feet in height and 14 feet across. Within the lanterns are columns of lenses forming two opposite sides of a hexagonal framework which rises from the base to near the top of each lantern. The whole framework can be made to revolve so that either column of lenses may be made to face in any direction; each column consists of three or four similar lenses superposed, but the lenses forming different columns are different in their purpose and structure, and in their size. One column in each lantern consists of lenses designed to gather the divergent rays which fall upon them from the central source of light into a level sheet which spreads over the surface of sea or land, but not downwards or upwards; each of these lenses is a segment of a cylinder, and may be described as a cylindrical lens. The opposite column in the gas and oil lanterns consists of lenses designed to gather the divergent rays, not into a sheet, but into a single cluster or cone of small vertical angle, which is sent forth horizontally in any one direction. These lenses are made up of a central circular lens, surrounded by annular prisms and segments of such prisms, the whole fitting into a rectangular frame; they may be called annular lenses. The corresponding column of lenses used with the electric light consists of cylindrical lenses with condensing prisms placed in front of them; the cylindrical lens flattens a broad cone of light into a fan, the condensing prisms close the fan.

The size of the cylindrical lenses placed in front of the gas and oil lamps is the same, but the lenses in front of the superposed electric lights are smaller. The annular lenses, of which three form a column in the oil lantern, are each 6 feet 3 inches in height, while the four superposed annular lenses in the gas lantern are each 3 feet 9 inches in height. Both sets of annular lenses have the same width, namely, 3 feet 5 inches.

The electric lights are large arc lights, supplied with the electric current by three magneto-electric machines, which are worked by the steam-engine in the engine-house built for the ordinary work of the station. The electrical apparatus is of the construction of Baron de Méritens.

The gas-burners tried hitherto are of Mr. Wigham's construction, consisting each of a multitude of small fish-tail jets on brass stems about 6 inches long and an inch one from another, arranged on the same level in concentric rings. A tall funnel, a few inches above the cluster of burners, draws their flames together into the form of a bell. The number of concentric rings may be changed quickly so as to increase or reduce the size of the burner from a diameter of about 4 inches with 28 jets, to a maximum of 11 inches diameter and 108 jets.

---

[1] Preliminary Report of Mr. Vernon Harcourt to the Board of Trade on the Experimental Lights exhibited at the South Foreland.

The oil lamps are of the usual Trinity House pattern with six concentric wicks, and are fed with paraffin oil.

Cannel gas is manufactured and stored at a short distance from the experimental towers, and supplied through a meter to the gas-burners.

For the observation of the lights, which were first shown in the week beginning March 30, three huts have been erected at different distances along a line perpendicular to the line of the towers, and this line has been marked by posts showing the distance from the central tower. The lighthouse-keepers who are stationed in one or other of these huts are instructed to make hourly observations during the time the lights are exhibited, expressing in figures their estimate of the relative brightness of the three lights. When the night is misty the keepers are instructed to patrol the line of posts, and to record the distance at which each light is lost or becomes visible. To avoid prejudice in favour of either an old or a new mode of lighting, the towers have been labelled, and are called A (electricity), B (gas), and C (oil). The huts are numbered. No. 1 is rather more than 700 yards distant from the central tower, No. 2, about 1⅙ mile, and No. 3, 2½ miles. Steps have also been taken to obtain estimates of the relative brightness of the three lights from observers at greater distances. To secure the identification in each hut of the lights observed when all three are not visible, three tubes have been fixed in each hut directed towards the lights A, B, and C, and labelled accordingly.

The huts serve also for measurements by various photometric methods of the light sent forth from each lantern. A number of such measurements have already been made, the results of which have been communicated to the Board of Trade by the Trinity House.

Near the engine-house on the South Foreland a long gallery has been built, in which the light emitted by the various lamps employed or proposed to be employed, can be measured so as to ascertain the value of these lamps independently of the lenses by which, within the lighthouse lanterns, their apparent brightness is variously augmented.

The experimental inquiry thus instituted will serve:—

(1) To ascertain the amount of light given by the six-wick and seven-wick oil-lamps, and of other oil-lamps, or modifications of them (if any) which may be proposed for lighthouse service.

(2) To ascertain similarly the amount of light given by Wigham's gas-burners on different scales (28, 48, 68, &c.) with different rates of consumption, and, if thought well, with different qualities of gas, and to test other gas-burners in like manner.

(3) To furnish further and trustworthy measurements of the light given by the electric arc with various carbons and with various tensions and quantities of electricity, and to test the efficiency of the De Méritens magneto-electric machines in converting mechanical into electrical energy, and whether they work without difficulty or risk of break-down or need of repair or loss of power; also to test the working of the De Méritens electric lamp, and of other electric lamps, if thought well.

(4) To furnish additional data for estimating the cost of maintaining any given light for a certain time, say 1000 candles for one hour, by each mode of producing light, and on the various scales suitable to different localities.

(5) To measure the efficiency of the lenses employed, especially with flames of different sizes in their foci.

(6) To prove experimentally (if such proof be desired) that 2 or 3 or *n* similar lights, when juxtaposed, give twice or thrice or *n* times as much light as a single light gives.

(7) To ascertain what light is sufficient to be visible from its horizon on a clear night, and in what ratio on the average of many nights the visibility of a light at great distances increases with its total intensity, or lens area, or proportion of red or of blue rays.

(8) To test the effect of the variations last named in haze, or mist, or fog, or rain, or snow, that is, when the air is made more or less opaque by particles of liquid or solid water of various sizes suspended in or falling through it. Such testing may be made either photometrically, which is only possible in slight haze and at small distances, or by observations of the distance at which each light is lost or reappears.

(9) To try the question of the utility of ex-focal light, whether, that is, it often happens that the position of a lighthouse may be seen by the illumination of cloud or fog above or around it, when its position would be unknown if equal light from a smaller focus were directed almost wholly towards the mariner, and not allowed to spread.

(10) To test further whether in mist or haze sudden flashes of a powerful beam of light are noticeable when an equal light maintained constantly, or waxing and waning gradually, would not be noticed.

It is likely that other subjects of experimental inquiry may be suggested by those experienced in lighthouse illumination, or may occur as the experiments proceed. But, taking those above enumerated in order, I will attempt to indicate the conclusions which at present appear probable, and to make some suggestions as to points still to be investigated.

(1) It appears that the six-wick oil lamp behind the annular lens sheds light of as great intensity as the seven-wick lamp, while its consumption of oil is much smaller. Probably this result is due, in part, to the fact that the outer ring of flame which the seventh wick adds is further from the focus of the lens, while each ring of flame is partially opaque to the light from the rings inside it; and partly to the fact that the seven-wick lamp has not yet been brought to so perfect an adjustment of oil-supply to air-supply as the six-wick lamp.

I do not know whether any oil-lamp used in other than English lighthouses is such as to merit a trial against the Trinity House lamp.

(2) Some observations have been made with Mr. Wigham's burners with 88 and with 108 jets, which seem to show that with gas as with oil, behind the annular lens, no gain in intensity of light results from the circaposition of another ring of flame. Some evenings should, I think, be devoted to trying this question out. The value of ex-focal light behind an annular lens seems to be almost *nil* as regards intensity, and, if so, it may be well to use with revolving light a smaller flame than that of the six-wick lamp. Excellent experiments on this question can be made with Mr. Wigham's burner by exhibiting on a clear night through the annular lens one of these burners, whose size should be reduced, after an interval sufficient for photometry, from 108 jets to 88, and so on to the smallest size, measuring also after each change the consumption of gas. It will probably be found that a large fraction of the *directed* light is still obtained with a relatively small consumption of gas, and with the accompanying advantage of a low temperature within the lantern.

Similar measurements should be made with a cylindrical lens and with the naked flame in the photometric shed.

At present one other gas-burner besides Mr. Wigham's has been tried, a ten-ring gas-burner devised by Sir J. Douglass, which has given an excellent yield of light. Two others, by W. Sugg and Co., and by the F. Siemens Company, await a trial. The problem which the maker has to solve is to pack as much highly luminous flame as possible into a sphere of 3 or 4 inches diameter.

Where gas has to be manufactured expressly for a lighthouse, it would generally be best to make cannel gas, but near a town where common gas could easily be laid on, it would be cheaper to use common gas. It might, therefore, be worth while during the course of the experiments to charge the small gas-holder with common gas, and to note the consumption and the light developed. It would probably be found that with suitable burners the chief disadvantage in using common gas was the greater development of heat, the same light being obtained from the consumption of a larger volume of lower priced gas.

(3) Many measurements have been made in recent years of the light of the electric arc, but the difficulty of making measurements of so variable a light, and the uncertainty attaching to the standards of light employed, and the great differences between one arc light and another, according to the electric current and the carbons employed, make it clearly desirable to have further measurements of the electric light at the South Foreland.

Photometry should be accompanied, as with oil and gas, by a measurement of consumption. The mechanical energy absorbed can be measured at the strap which connects the magneto-electric machine with the steam-engine. The electrical energy developed can be measured in tension maintained, and quantity used, at the leads connecting the machine with lantern A. The cost of each horse-power per hour on the actual scale of working at the South Foreland must be already known. The rate at which the two forms of carbons which have been tried are consumed is also known.

It is essential to the value and significance of the photometry that simultaneous electrical measurements should be made.

The possible variations in the coupling of the magneto-electric machines, in the rate of running, and in the nature, form, and adjustment of the carbons, present a wide field of experimenting.

The continuance of the experimental working for many months will serve for a trial of the trustworthiness of the De Mériten's apparatus for lighthouse service.

(4) The cost of maintaining a lighthouse supplied with gas has been very variously estimated. It must vary from place to place, especially with the price of coal. The actual working expenses of oil lighthouses on the English coast, and gas lighthouses on the Irish coast, with allowance for the price of coal and labour, should furnish trustworthy data for a comparison. But to complete these data the quantity of light produced and utilised in each case needs also to be known, and as both the oil and gas burners tried hitherto at the South Foreland are of the service kind, the photometry now in progress will supply this knowledge. Some information may also be gathered from the expenditure on each illuminant at the outset and during the course of the experiment. It should be possible to state, if it were desired to maintain on the South Foreland a light of 50 or 100 or 200 thousand candles, what its annual cost cost would be with each illuminant.

(5) Although the action of lenses is mainly calculable, and, so far, does not require trial, it is modified by two quantities which vary slightly, namely, the reflection and absorption of light by glass, and is affected to some extent by errors of workmanship. It will, therefore, be of interest to obtain an exact comparison between the light emitted by a naked flame, and that from the same flame concentrated by different types of lighthouse lens. The prediction of the effect of a lens is less possible when the illuminant is of large size; and the failure of lenses, constructed for use as a revolving light with gas, to utilise (except by broadening the beam) the light produced at a distance of more than two or three inches from the focus of the lens, if they are found to fail so far, may be worth demonstrating.

With the electric light a very close correspondence should be found between the calculated effect of the cylindrical lens and of the condensing prisms and the results of photometry.

(6) The measurements which have been made of multiform gas and oil may be taken to show that any number of lights at a given distance cause so many times the illumination which one light causes; or assuming that the above must be the case, and is involved in the conception of comparative illumination, the proportional variation of the photometric results with the changes from uniform to biform, &c., on clear nights, gives evidence of the trustworthiness of the photometric methods.

(7 and 8) The two questions, which I have numbered thus, can hardly be treated separately, since clearness differs only in degree from slight haze, and slight haze from fog. Together they constitute the chief object of this inquiry.

The observations of the experimental lights which have been made from a distance, may be expected to yield, when they are collected and compared, much information as to the distances at which the several lights have been seen in various weather. But the changes which are necessary when photometric testings are to be made, or when an extensive programme is to be exhibited, must to some extent have interfered with the observation of the changes due to variations in the transparency of the atmosphere. It might be well for at least one month, to show the same lights nightly, and to inform the distant observers that this was about to be done, in order that their observations might have the more value. A single light of each kind shown through the cylindrical lenses would serve as well as multiform lights, and it would be best to use that size of gas-burner which had through the lens equal illuminating power with the six-wick oil lamp. Unless, indeed, it is assumed, as I should be inclined to assume, that equal lights from gas and oil have the same power of penetrating haze; in which case it would be more instructive to show from tower A a single electric light supplied from one machine, and from B and C either gas or oil also single, and either oil or gas of such size and number as to have at close quarters on a clear night an illuminating power equal to that of the electric light. A sufficient series of distant observations of these lights would show (1) whether the electric light maintained its equality with the larger hydrocarbon flame through slight haze, or became more nearly equal to a flame of much less initial brightness; and (2) whether the taller beam of multiform oil or gas had much advantage over the beam sent forth from a single lens. I believe it will be found that the relative brightness of two, or more, to one, will be maintained at any distance and through any haze which permits of photometry, but that, when the single light is lost at 5 miles or 500 yards, the triple light will be invisible at 6. The actual figures corresponding to these conjectural figures must be found, and the Trinity House Committee will then be able to judge in what cases such an extension of range is worth the increased expenditure.

In the case of the electric light, the observations which have already been made show that it loses in haze a larger proportion than the hydrocarbon flames. Further observations on this point will be of much interest and importance. The most valuable are observations of the distances at which an electric and a gas or oil light, whose relation in clear weather is known, cease to be visible. Such observations are strictly photometric observations, in which the lights observed are brought to an equality of minimum appreciable brightness, and the distances at which their brightness is equal are measured. These are dependent upon the weather, and may be practicable on only a few days in each month. Still more rarely will the opportunity offer of measuring the lights in hut No. 1 through a slight uniform mist; but such measurements ought to be made. I would suggest the possibility of testing in the photometric shed through an artificial mist produced by blowing steam from the boiler in the adjoining engine-house into the middle of the shed.

It is said that Faraday proposed at first the use of a very small lens with the electric light. Unless conclusive experiments have been made on this point, it may be well to place the experimental electric light in the focus of a larger and of a smaller annular lens, each subtending the same angle, and to note whether the effect differs.

It might also be worth trying whether biform gas, with a small enough number of jets to have the same illuminating power as single oil, would be better seen through slight haze. The trial would not be between gas and oil, but between placing a strong light behind one lens, and placing half the light behind each of two superposed lenses.

(9) Owing to the nearness of the three lanterns, the illumination or halo which spreads round each of them in a fog seems almost to blend. That which surrounds the gas lantern is not much greater than that around its neighbours on either side. I do not think that, on the one occasion on which I have seen the lights in a fog, the ex-focal light was of much service.

If a lighthouse lantern was surrounded by a mist or cloud extending far enough laterally to extinguish its principal beam, but so little above it as to allow the scattered light to fall upon a higher stratum of cloud, the position of the lighthouse might only be seen from the illumination of the cloud above it. But this state of things would happen rarely in most places, and a better plan of turning it to account than the addition to a burner of rings of ex-focal flame would be to employ the upper prisms to send a second beam skyward. Whether the general illumination about the experimental lanterns has been visible when the three centres of light were not visible to an observer towards whom the beams were directed, may perhaps be gathered from the record of observations.

(10) When engaged on a clear night in judging of the experimental lights, the eye of the observer is continually caught by the sudden flashes of the Calais light. The revolving light at Grisnez is equally visible, but does not catch the eye in the same manner. It might be well to try on some rather hazy night, whether, if one lantern alone were lighted, and during successive quarters of an hour the light were alternately kept steady and flashed in some such groups of flashes as the Calais light, the observers patrolling the line of posts became aware of the light at a greater distance when it was flashed than when it was steady or revolving. Even a slight mist is a great leveller of distinctions, but it seems possible that the use of flashing may increase the range of a light as much as an addition to its intensity or size.

Some of the questions raised in the latter part of this report might perhaps have been omitted, as having already received an answer, if, while thinking the matter over, I had been able to consult some of the experienced members of the Trinity House Committee who are charged with the conduct of this inquiry. I have ventured here in writing, as at other times by word of mouth, to make the suggestions which have occurred to me, knowing that they will receive friendly attention if they are submitted to the Committee, and hoping that some of them may be of service. (Signed)

July 26, 1884 A. VERNON HARCOURT

Since[1] the foregoing preliminary report was presented to the Board of Trade, the experimental inquiry has come to an end, and a complete account of the apparatus, observations, and testings has been published by the Committee of the Trinity House who had charge of the inquiry, followed by a statement of the conclusions at which the Committee have arrived.

I propose to arrange the remarks I have to offer under the following heads:—

I.—Apparatus for the exhibition of the experimental lights.
II.—Arrangements for observation.
III.—Photometry.
IV.—Comparison of lights.
V.—Range of lights in hazy weather.
VI.—Cost of each system.

I.—*Apparatus for the Exhibition of Experimental Lights*

In my preliminary report I have given a general description of the temporary towers, the lenses and lamps. In Parts I. and II. of the Trinity House Report are to be found plans and measurements giving the full details of these constructions. The towers are admirably suited to their purpose, and their situation and the distance between them proved most convenient for observation.

In regard to the arrangements for exhibiting the electric light, it is to be observed that, although the electric light completely outshone its competitors, it was heavily handicapped in the competition. The "leads" were not of sufficient calibre to carry the large electrical currents used, for a distance of nearly 300 yards, without considerable loss. Prof. Adams estimates the loss at more than one-fourth the electrical energy supplied.

The five vertical prisms used in the case of the electric arc to bring together the horizontal rays, subtended an angle of only 30°, while the annular lenses which served the same purpose in the gas and oil lanterns subtended an angle of 60°. Thus the fraction of the light emitted from the central source of light, which composed the revolving beam, was only half as great in the case of the electric arc, as in the case of the gas and oil flames. It seems probable also that a beam of less divergence may be used with advantage to obtain a maximum range in hazy weather; and such a beam may be obtained from the electric arc with lenses of moderate size. On a few occasions when an annular lens similar to those used in the other two lanterns was placed in front of the electric arc, the light was dazzling at a distance of more than a mile, and surprisingly vivid at a distance of 20 miles. I see that on a clear night when the 108-jet gas burner behind an annular lens gave a light of 60,000 candles, the electric arc behind its cylindrical lens and vertical prisms gave a light of 1,200,000 candles, and behind an annular lens a light of 12,000,000 candles. In the one case the arc was five times as powerful as Mr. Wigham's "quadriform," in the other fifty times as powerful.

For the sake of uniformity and comparison under similar conditions, only the central belt of the Fresnel apparatus was placed round the electric lamp as round the gas and oil burners. The suppression of the top and bottom prisms, though entailing a loss of 30 per cent. of the light produced, is a necessary sacrifice where large burners developing great heat are placed immediately one over the other. But each of the electric lamps in tower A might have been surrounded with a complete Fresnel apparatus, adding nearly one-third to their light, without any difficulty or any necessity for separating them more widely.

Thus, if the principle which has been enunciated had been followed, of doing for each illuminant the best that could be done within the limits of the lighthouse lantern, if a triform electric light had been exhibited, with leads of low resistance, with a lens subtending an angle of 60°, and with top and bottom prisms, the power of this light might have been more than tripled. By also reducing the divergence of the beam, which I think might be done with advantage, a further increase of power could have been gained. This fact should be borne in mind in comparing the results which were obtained with the three illuminants.

In M. Allard's interesting and important "Mémoire sur les Phares électriques," 1880, he gives the results of a trial of three Gramme dynamo-machines and an electro-magnetic machine of the Alliance Company. The former gave for the same horse-power 40 or 45 per cent. more light than the latter. But M. Allard measured only horse-power and light, not the electrical energy developed; and it does not appear whether the larger yield of light was due to a more powerful electrical current, or to the position of the carbons, and the form of the incandescent ends, being more favourable to the emission of light with the continuous current. Probably the De Méritens machines, which produced a light of about 1000 candles per horse-power, are superior to those of the Alliance Company, which yielded only 540 candles, and are equal to the Gramme machines which yielded 800 candles per horse-power. Of all that relates to the economical production of powerful arc lights, knowledge is advancing rapidly. The ample provision of steam power, and the excellent photometric gallery at the South Foreland, will no doubt be used from time to time for the trial of new types of electrical machines, of regulators, and of carbons. For the past experiment, and apart from the question of cost, the De Méritens machines worked admirably, converting, according to the measurements of Prof. Adams, mechanical into electrical energy with a loss of only 16 per cent. The current supplied was more than sufficient for the largest carbons; indeed, carbons exceeding 1½ inches in diameter were heated to redness through their entire length.

In regard to the apparatus for exhibiting the gas system of Mr. Wigham and the oil lamps of the Trinity House, little can be added to the full and clear account of the Trinity House Committee. But as it has been stated, since the publication of the Trinity House Report, that Mr. Wigham's foreman was not left unfettered to make the best display which the apparatus in his charge would allow, I may here put on record what I saw and believe in the matter. I paid many visits to the gas lighthouse by day and by night, and was in frequent communication with the foreman, Mr. Higginbotham, from the beginning to the close of the experiments. The arrangement of each night's programme rested with the Committee of the Trinity House, who so ordered matters that abundant opportunity was given for the observation and measurement of all the varieties of each illuminant. Among these were Mr. Wigham's combinations of 28 jets, 48 jets, 68 jets, 88 jets, and 108 jets, the ready conversion of one of which into another is among the merits of his ingeniously constructed burner. When the effect of the smaller number of jets was to be observed, it is clear that the full power of the burner could not also be shown. Therefore, there were necessarily times when Mr. Wigham's foreman was not free to make the best display which the apparatus in his charge would allow. With this exception only, I believe that Mr. Wigham's foreman was perfectly free to do his best and make any improvements Mr. Wigham or he could devise. I see from the summary in the Trinity House Report that the full power of Mr. Wigham's burners was shown on 127 nights; and it appears from the photometric record that it was measured 57 times. This ought to suffice for an accurate judgment of its merits.

Comparing the gas and oil towers as they appeared to a visitor when in full operation, the gas had one striking advantage, and one equally obvious disadvantage. The advantage was that it needed no care. When the lenses had not to be revolved by hand, nor the number of jets changed, one attendant in the tower was sufficient, and he had little or nothing to do. In the oil tower, on the other hand, I have seen a keeper on every one of the three stages, each man watching and from time to time adjusting his lamp. The disadvantage encountered in the gas tower was the excessive heat from the large gas-burners, which by causing unequal expansion of the glass lenses and their metal framing, and of the outer and inner surfaces of the lenses themselves, caused cracks to appear, which in the continuous belt of thick glass gradually spread from side to side. But though the burning of gas yields for the same light more heat than the burning of oil, there is no reason to think that with a diminished consumption of gas, *e.g.* the 160 cubic feet an hour of the 68 jets instead of the 300 of the 108 jets, such a disaster would recur. When the gas flame is surrounded by a chimney, as in Sir James Douglass's and Mr. Sugg's multiple Argands, the heating of the lenses is greatly diminished.

When the lights were first exhibited, the behaviour of the oil lamps in C tower was a matter of much interest. Using gas, Mr. Wigham had succeeded in quadrupling the power of a large burner behind a lens more than a yard square, by placing over it three other similar burners and lenses. But it seemed a hazardous experiment to imitate this plan by placing three lamps fed with mineral oil one over the other. However, the skilful arrangements of Sir James Douglass were completely successful. The three superposed oil lamps burnt as safely and well as if each had had the lantern to itself.

---

[1] Further Report of Mr. Vernon Harcourt to the Board of Trade on the Experimental Lights exhibited at the South Foreland.

II.—*Arrangements for Observation*

A short account of these arrangements have been given in my previous report, and a complete account is to be found in the report of the Trinity House Committee.

The plans for making observations on shore at small distances had been well laid. The home at St. Margaret's, stationed between the two observing huts, with telephone to all points; the measured distances; the huts themselves, welcome refuges on a cold night, and most convenient for photometry with their helpful occupants; all bore witness to the wise forethought which had been bestowed upon the details of the inquiry.

For obtaining records of the relative brightness of the different lights from the impressions of those who saw them, probably no better plan could have been devised than that of distributing forms to be filled in with a numerical estimate of the ratio which two of the lights bore to the third. And the enlisting a multitude of observers, by the wide distribution of these forms, secured the two advantages, of an average drawn from a very large number of observations, and of an obviously impartial judgment. The observations made at sea from the Trinity House yacht *Argus*, which was in constant attendance, were of great importance; and I may add that, for the landsmen whose main business was photometry at small distances on shore, taking part in these observations was an essential help towards the full appreciation of the problem before them.

III.—*Photometry*

The chief assistance which I found myself able to render to the Committee was in devising and improving photometric apparatus and methods. A full description of these is given in the Committee's Report, especially in Mr. Dixon's "Record," part ii., pp. 30-36. During my visits to the South Foreland, I was principally occupied with photometry, in the dark gallery by day, and in one of the huts by night. Frequently Mr. Longford or Mr. Dixon worked with me, and the observations which I made are included in the general record. I believe that the standard of light employed was constant and of a definite and reproducible value, and that the methods of comparison were trustworthy and accurate. The excellent idea of Sir James Douglass, of using a large lens to concentrate the rays from the lighthouses upon the photometric disk, made possible the measurement in the more distant hut of lights whose intensity was too feeble to be accurately estimated without such aid. Mr. Dixon's polariscope photometer and the ingenious obscuration photometer of Captain Nisbet, are instruments well adapted for the direct comparison of distant lights or lights enfeebled by haze; the former can only be used for lights which are near together. Two movable photometer-bars, designed by Sir James Douglass, and suitable for use with any form of disk and any standard, were in constant employment throughout the trial. These were placed in the photometric gallery and in hut II. The observations in hut I. were reduced by means of a portable bar devised and made by Mr. Dixon.

A glance at the 16 columns of the closely-printed photometric record,—each number being, as a rule, the average of many observations,—will give to those who know the effort of attention which accurate photometry requires a conception of the diligence with which this branch of the inquiry was pursued. I have spent many hours in one or other of the huts with Mr. Dixon or Mr. Longford, and I wish to express my conviction that the results which they obtained and which are printed in the Trinity House Report, are as complete and trustworthy as zealous, patient, and skilful work could make them.

IV.—*Comparison of Lights*

Although an observer's opinion on the relative brightness of two or more lights, like an opinion on the force of the wind, is better expressed by means of numbers than by descriptive terms, such numbers must not be regarded as expressing the relative intensity of the lights so compared. Perhaps on any future occasion it would be better to call the brightest light 10 rather than 100, since the use of the larger number suggests that an inferiority just sufficient to be noted with confidence is to be expressed by a difference of 2 or 3 per cent., whereas it probably amounts to at least 10 per cent., and 9/10 or 8/10 would be nearer the ratio of the two lights than 98/100 or 95/100. No doubt by practice in comparing lights whose relative intensity is known, a fair power of judging may be acquired; but without such training the natural tendency is to under-estimate differences. For example, the average of 294 estimates by eye of the relative power of "triform oil" and "quadriform gas," assigns to the gas a superiority of 6 per cent., whereas the actual superiority as shown by measurement is 23 per cent. According to the same series of estimates the electric light has a superiority over "quadriform gas" of 59 per cent., the actual superiority being more than 400 per cent.

Equally remarkable evidence of the tendency to overlook differences of intensity when the estimate is made directly by eye, is found on comparing the values assigned to "multiform" lights. The figures relating to the 108-jet gas-burners, and representing the relative value of the single, biform, triform, and quadriform lights, each by comparison with the electric light, are 56, 61, 59, and 63. If these numbers represented the intensity of the light falling upon the eye from the whole surface of the illuminated lenses, they should stand in the ratio of 1, 2, 3, and 4. The explanation at once suggests itself that while the photometer measures the total light received from a large illuminated surface, the eye judges of the brightness of the surface or the light received from equal areas. To an observer looking down a street on a clear night, the more distant gaslights seem as bright as those which are nearer, though smaller in size; if asked to estimate the lights he would probably assign the same figure to all. And the visual angle subtended by the flame of a street-lamp at 100 yards is about the same as that subtended by 18 feet of lenses at a distance of 4 miles. The singular fact that as estimated by eye, on a separate comparison with the electric light, "multiform" have no superiority to single lights, may to a small extent admit of the explanation which applies to the familiar case which has been given. In this case the observer distinguishes between size and brightness, and sets himself to judge of the latter only; or it may be that the intensity of the sensation of light depends upon the brightness and not the size of the spot of light formed upon the retina. But the South Foreland observations were not made chiefly at distances of only 2 or 3 miles; nor were the observers likely to disregard the apparent magnitude of a light in estimating its value. At distances of from 12 to 14 miles, at which the largest lights have no appreciable magnitude, the average values assigned to the biform, triform, and quadriform lights are 75, 66, and 60.

I fear the true explanation is that the results have suffered from the electric light having been adopted as the term of comparison. To a small extent its fluctuations and difference of colour, and to a much greater extent its incomparable power, have made the estimates entirely uncertain; and thus it is vain to institute cross comparisons between the different lights which were not seen together, but only estimated by reference to the electric light as a standard. This conclusion, however, does not affect the value of the comparisons, chiefly aimed at, between the gas and oil lights, which were seen together, nor the significance of the direct comparison of the flame lights with the electric light at all distances and in all weathers. Indeed, the adoption of the electric light as the standard with which all others were to be compared, has served to establish on the basis of thousands of observations the important fact that, as far as the eye can judge, the electric light appears to excel the light of gas or oil lamps almost as much at greater as at smaller distances, and in hazy weather as in clear. The mean ratio of the electric light to all the gas and oil lights exhibited, taken from the whole number of recorded observations, is, at distances of from 1 to 8 miles 1000/626, at distances of from 8 to 15 miles 1000/613. In clear weather the mean ratio is 1000/591; in weather not clear it is 1000/608.

The photometric record presents many points of interest.

In the measurement of naked flames the long gallery, which has wisely been made a permanent structure at the South Foreland, afforded unexampled facilities. The electric arc was measured at a distance sufficiently great for its intensity to be similar to that of the other lights which were measured. The values assigned to it, from 10,000 to 15,000 candles, are not so high as some which have been obtained; but this is perhaps due to the fact that extreme values were rejected, and care was taken to obtain an average result.

In one respect the observations are incomplete, and need to be supplemented at some future time. Within the lighthouse the source of light is surrounded by an apparatus which gathers together the light sent forth in all directions, excepting a small angle above and below. Thus, the intensity of the light sent in a sloping direction upwards and downwards is of as great importance as that of the light sent forth in the horizontal plane. But only the latter has hitherto been measured in the photometric gallery. According to M. Allard the electric arc produced by an alternate current sends out horizontally an amount of light which is 11 per cent. greater than the average amount sent in all directions. With a continuous current the strongest light is thrown on the side opposite to the positive carbon; but it happens that with an arc light of this description horizontal measurement gives the average value. Probably Mr. Wigham's wide cluster of gas jets sends forth less light horizontally, owing to the imperfect transparency of one flame to the light of another, than it sends in an upward direction; and the same may be the case with the concentric gas-burners and oil lamps. Mirrors might hereafter be arranged within the photometric gallery, which would serve for making these measurements.

To determine accurately at a distance the power of the various lights exhibited was an essential preliminary to calculating the range of any of the lights in hazy weather. And although this power is approximately calculable, the power and dimensions of each flame, and the structure of each lens being known, it was of great interest to make actual measurements of the intensity of the light at two different points, and in different states of the atmosphere. I am not aware that such measurements had ever before been attempted. Owing to the novelty of the photometric problem, and to some extent of the methods employed, it was highly important to have some means of testing how far the results were trustworthy. Such means were furnished by the multiform system of Mr. Wigham. At any distance, and in any state of the atmosphere, the illumination produced by a combination of two or more similar lamps and lenses is so many times as great as the illumination produced by a single lamp and lens of the same kind. Thus, among the lights to be measured were several whose relative power was known beforehand. If testings of single and multiform lights, made in succession while the degree of clearness of the air was unchanged, gave values varying approximately as the number of lights, an equal degree of exactness may be ascribed to the testings of other lights and lenses.

On July 12, the weather being "clear, calm, overcast," the light from the single, biform, triform, and quadriform 108-jet burners, showing through Mew Island lenses, was measured at hut I. The results in thousands of candles were 50, 98, 168, and 214. Three testings intervened between the second and third, and probably the air had become a little clearer, but the numbers are not far from the ratio 1, 2, 3, 4. Three days later the same single, triform, and quadriform combinations were tested one after the other, also at hut I. The values found are 48, 145, and 186. Similar testings were made on July 23, on a clearer night, of all four combinations; their power was found to be 58, 112, 171, and 220 thousands of candles. Probable values in the ratio of 1, 2, 3, 4, are 56, 112, 168, and 224. On the same night the value found for a single six-wick oil lamp behind an Eddystone lens was 56,000 candles, and for three such lamps behind three such lenses 168,000 candles. On November 1, in thick haze, the value found at the nearer hut for "I. Gas, 108, M.," was 25,500 candles, and for "IV. Gas, 108, M.," 102,000. The results obtained at hut II., with a wholly different photometer, are confirmed in the same manner. For example, on February 7, consecutive testings on a misty night of "single" and "quadriform gas" gave in thousands of candles the numbers 26 and 101. On March 20, on a very clear night, the values found for the same two lights were 63 and 252.

In looking over the tables of the photometric record, and comparing the figures standing against combinations of equal numbers of oil lamps behind Eddystone lenses, and of the larger gas-burners behind Mew Island lenses, in all weathers in which the lights were measurable, the eye is struck by the similarity of the numbers. The rival systems are nearly equal; there is little to choose between them. Still less difference, as has been pointed out, was discernible on looking, as we did night after night, at the lights themselves. Other considerations than that of visibility in either clear or hazy whether, must decide which, if either, of the two systems is to be generally adopted for lighting our coasts. By multiplying burners and lenses, and by enlarging the size of the lenses, more powerful lights still may be produced, if it is thought desirable, with either illuminant.

But the most prominent fact on the face of the photometric record is the immense superiority of the electric light. The conclusion forces itself upon the reader of these tables that if greater power is needed, it is to be found, not by magnifying lenses or multiplying combinations of gas or oil burners, but by substituting the light of the electric arc.

The Trinity House Committee report that the electric light in clear weather is certainly not popular with sailors, chiefly on account of its dazzling effect at short ranges. But at ranges exceeding two or three miles, "hyper-radiant," or even multiform lenses, are not visibly larger than such a lens as is suitable to the electric arc; and at such ranges the "dazzling effect" is simply that due to the power of the light. If a double quadriform were as powerful it would dazzle as much. Also the use of a powerful electric arc in clear weather may be avoided. It would not be difficult to arrange for the use of a small electric arc during clear weather, and the quick substitution of a powerful arc light when the weather became hazy. I would venture to suggest that the singular circumstance which led or contributed to the removal of the electric light at Dungeness, that a vessel went ashore near the lighthouse, may have been due, not to the dazzling effect of the light, but rather to the diminution of brightness as the approaching vessel passed within and beneath the range of the light. With the condensed and sharply-defined beam of the electric light, it may perhaps be desirable to devote some part of the optical apparatus to spreading a portion of the light over the space intervening between the coast and the point, a mile or two away, at which the principal beam first strikes the sea. If this is done, the light at short ranges might be made sufficient, but not too dazzling; and for longer ranges there seems to be no reason why the powerful beam produced by the electric arc behind one of the Mew Island lenses should not be employed. This beam had a divergence of about 1°. Even from the high level of the South Foreland lights, if the axis of such a beam were so inclined that only about $\frac{1}{8}$ of the light passed over the horizon, the full light would extend to within about three miles of the shore. Since the apparent brightness of every light must vary with the state of the atmosphere, as well as with the distance of the light, and as the angle subtended, even by a multiform light, at a few miles distance is very small, it cannot be possible by the appearance of a light without other data to judge of its distance. The electric light is not singular in this respect.

(*To be continued.*)

THE LUMBAR CURVE IN MAN AND APES

We are indebted to Prof. Cunningham, of Trinity College, Dublin, for a well-illustrated and exhaustive memoir on the subject of the lumbar curve in man and apes. This memoir has been printed by the Royal Irish Academy as one of the Cunningham Memoirs, and is illustrated by thirteen plates, several of which are large folding ones, and two of which are large coloured drawings of the two surfaces of a mesial section of a male chimpanzee; these are life-size, and are the first accurate representations of the topographical anatomy of this anthropomorphic ape we have seen.

The structural differences between man and the anthropoid apes are no doubt in a great measure due to the assumption by man of an erect attitude, and to his having from an early period of his life dispensed with the use of his anterior extremities as organs of locomotion. The vertebral column of man might be expected to exhibit in a marked degree differences distinguishing it from other animals, and that more or less deep convexity forwards in the region of the loins has been considered by some not only as a marked character of the human spine but even as peculiar to humanity; other anatomists have denied that this is so, and consider that man and certain of the man-like apes have it in common. In this memoir Prof. Cunningham seems to minimise the importance of the lumbar curve as a distinctive character of any special group. Not only the higher, but also the majority of the lower apes, possess this curve; and, under